# Data Resources for Hazard Modeling in Building Interiors


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## Objectives

- **Different approaches for interior building modeling**
  - Data requirements
  - Ease of set-up
  - Run time requirements
  - Output interpretation
- **Existing Datasets from Consequence Management ACTD**
  - Simulated convention center
  - Simulated apartment building
- **Conclusions for First Responders**

## Interior Building Models

- **HAZCB (SAIC)**
  - Multizonal model, with sub-grid capability
- **FAST-3D (Naval Research Lab)**
  - Full CFD model
- **GASFLOW (Los Alamos National Lab)**
  - Full CFD model
- **MIDAS-AT (PLG, Inc.)**
  - Multizonal model
- **CONTAIN (Sandia National Lab)**
  - Multizonal model
- **COMIS (Lawrence Berkeley National Lab)**
  - Multizonal model
- **CONTAM (NIST)**
  - Multizonal model

## Data Requirements

**Correctly predicting indoor hazards depends critically on the following data:**

- **Facility characterization data (building leakage, etc.)**
- **HVAC characterization data**
- **Source characterization (release time, duration, size, agent, position)**
- **Meteorological data**

## Facility Characterization


## Meteorology Measurements

- Measured data should include wind speed and direction, ambient (exterior) temperature, humidity, air pressure
- Concurrent measurements of interior room temperatures and temp gradients (time-tagged)

# Consequence Management (911-Bio) ACTD

**PURPOSE - Enhance world wide military capability to respond effectively to the use of chemical or biological weapons by demonstrating:**

- Key weapons of mass destruction consequence management technologies in a field environment and validating research priorities
- Operational concepts of the US Army Technical Escort Unit (TEU) and US Marine Corps Chemical Biological Incident Response Force (CBIRF)
- Ability of DoD units to integrate with other Federal, State, and Local agencies

- Preliminary Demonstration held 3-4 June 97
- Final Demonstration held 4-8 December 97

# 911-Bio ACTD M&S Study Objectives

- **Problem: DoD's accepted hazard prediction capability treats outdoor conditions, limited terrain**
  - **® Not applicable to 911-Bio ACTD scenarios**
- **Solution: Bring ensemble of models together, and evaluate them for "operational applicability"**
  - Select models developed for other applications that can be easily applied to ACTD conditions
    - Reactor Containment
    - Complex Airflow
    - Fire Code development
  - Different solution methods
    - Multizonal models
    - CFD models
- **Secondary Goal: Develop "ground truth" data set for interior building modeling**

## Test Methodology

- **Characterized the facilities**
  - Leakage rates
  - HVAC flow rates
- **Provided data to modelers**
  - Facility and meteorology data
  - Source characterization
- **Modelers prepared time-resolved aerosol concentration predictions**
- **Performed release, measured tracer gas and bio-simulant (spore) concentration as a function of time at different locations**
- **Compared blind predictions to measured data**

## 911-Bio M&S Study Conclusions (1 of 2)

- **When properly used, M&S tools are useful in a domestic Consequence Management (CM) scenario, for planning, training, operations, and analysis**
- **There is not one superior model type for all these applications. It is necessary to identify the question(s) that you want M&S to answer, and then choose the model type based on the question**
- **Important to understand thoroughly the limitations of the models that you are using**

## 911-Bio M&S Study Conclusions (2 of 2)

- **In their current state, M&S tools are not useful to first responders for Consequence Management operations while in the "hot zone"**
  - User interfaces are not friendly
  - Difficult to set up models
  - Output data is not well suited to first responders

**At this time, for CM operations, M&S is better suited to on-site headquarters than in hands of first responders.**

## Scenario 1

- **Simulated anthrax attack on a convention center**
- **Hangar at Dugway's Michael Army Airfield used to mock up convention center hall**
- **Full instrumentation suite installed**
  - Environmental conditions
  - Tracer gas concentration
  - Biosimulant concentration
- **Facility characterization**

## International Computer Expo at the "Los Angeles Convention Center"

2/25/03 4:41 PM

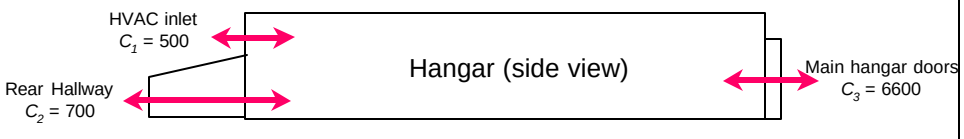
## Hangar Leakage Characterization

- Hangar leakage can be expressed in terms of the flow equation:

$$Q = C_i \times \Delta P^n$$

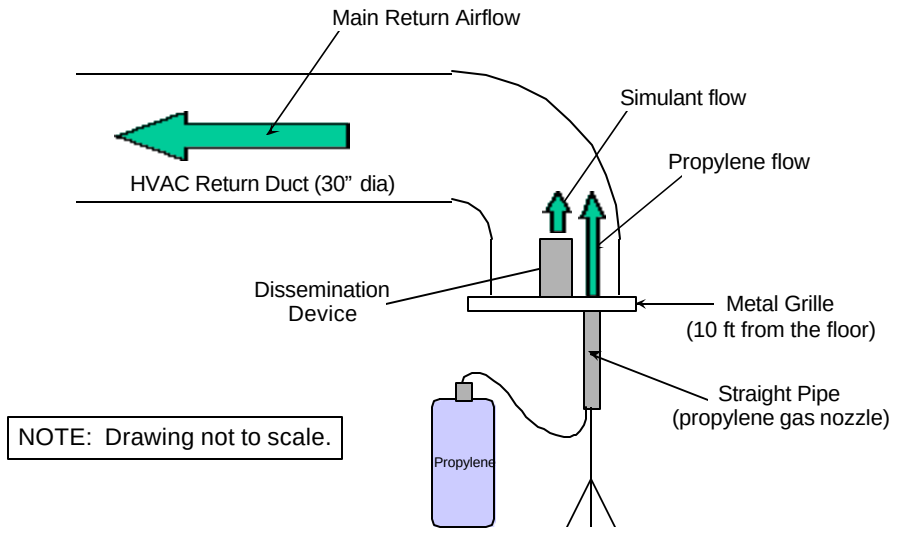
where $n = 0.635$ (measured value) and $C_i$ is a constant (measured for each leakage location in the hangar).

- Three distinct leakage locations were identified, indicated by the arrows in the sketch below (with corresponding measured flow constants):




Note that the HVAC inlet is only a leakage point when the HVAC system is turned *off*.

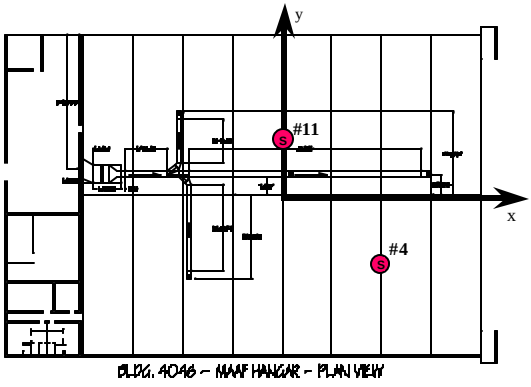
# Release Geometry




NOTE: Drawing not to scale.

# Hangar Ground Truth Data

Two locations inside the hangar were selected to focus the modeling predictions. These sites were fully instrumented to provide measured data for comparison with the predictions.



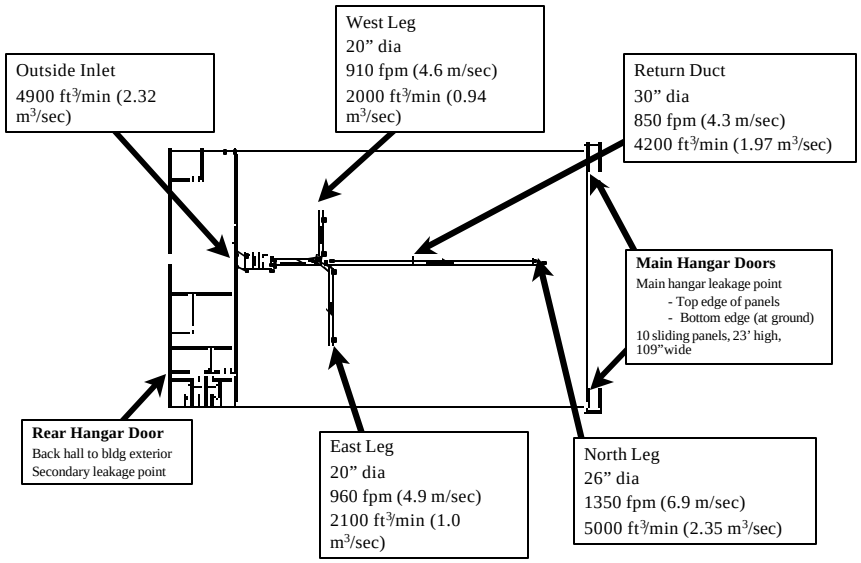

Ⓢ Specified locations for predictions and sensors

# Hangar Coordinates (sensors, etc.)

| Item Description | X (m) | Y (m) | Z (m) |
|---|---|---|---|
| Propylene Sampler #1 (w/ slit sampler) | -12.15 | -6.65 | 2.00 |
| Propylene Sampler #2 (w/ slit sampler) | 0.00 | -6.65 | 2.00 |
| Propylene Sampler #3 (w/ slit sampler) | 6.15 | -0.55 | 1.40 |
| Propylene Sampler #4 (w/ slit sampler) | 12.40 | -6.65 | 2.00 |
| Propylene Sampler #9 (w/ slit sampler) | -12.15 | 7.15 | 2.00 |
| Propylene Sampler #10 (w/ slit sampler) | -6.05 | -0.50 | 1.40 |
| Propylene Sampler #11 (w/ slit sampler) | 0.00 | 7.15 | 2.00 |
| Propylene Sampler #12 (w/ slit sampler) | 12.40 | 7.15 | 2.00 |
| Vertical Temperature Profile (four sensors) | 12.20 | -1.20 | 2,4,6,8 |
| North Leg HVAC Outlet (center of bottom) | 17.35 | 2.85 | 5.45 |
| East Leg HVAC Outlet (center of bottom) | -11.60 | -17.35 | 5.75 |
| West Leg HVAC Outlet (center of bottom) | -12.95 | 9.90 | 5.75 |
| Return Duct HVAC Inlet (center of opening) | -1.30 | 2.85 | 3.10 |
| Center Curtain opening (upper west corner) | 0.00 | 11.90 | 4.70 |
| Center Curtain opening (upper east corner) | 0.00 | -11.90 | 4.70 |

Note: Measurements are in meters, with the origin at the geometric center of the hangar floor. Gray-shaded locations are designated for ground truth comparisons.

# HVAC Characterization - MAAF Hangar

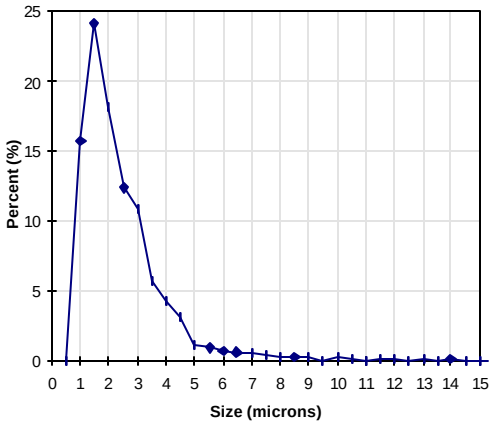


# Release Parameters

- **Anthrax Simulant (*Bacillus subtillis* var. *niger*, or BG)**
  - Total of 98 grams released at 1000 hrs, 30 May 1997
  - 90% released in first 30 sec, balance in next 30 sec
  - Velocity out of disseminator device 150 fpm
  - Aerosol particle sizes ranged roughly from 1 to 10 microns
- **Propylene**
  - 150 liters per minute for 1 minute (approx 280 grams)
  - Low velocity from nozzle pipe (local return airflow ~1000 fpm around the dissemination device)
- **Airflow characteristics**
  - All hangar doors closed and HVAC turned on 20 minutes before release
  - HVAC turned off at 1040 hrs, 30 May 1997

# BG Size Distribution

- **Measured with an aerosol particle sizer (APS); data summed over the first five minutes of the release**
- **Size distribution grouped into even sized "bins" of 0.5 mm**
- **91% are 4 mm or smaller, more than 99.9% are 0.5 mm or larger**



# Wind Data (1 of 2)

| | | Speed (knots) | |
|---|---|---|---|
| Local Time | Direction | Avg | Max |
| 1000 | 46 | 1.6 | 3.6 |
| 1005 | 7 | 1.2 | 4 |
| 1010 | 33 | 0.1 | 1.3 |
| 1015 | 199 | 1.3 | 3.2 |
| 1020 | 265 | 1.9 | 5.1 |
| 1025 | 304 | 1.3 | 2.7 |
| 1030 | 278 | 2.1 | 3.8 |
| 1035 | 277 | 2 | 5.7 |
| 1040 | 272 | 1.5 | 4.9 |
| 1045 | 237 | 0.9 | 3.6 |
| 1050 | 268 | 2.8 | 4.6 |
| 1055 | 272 | 2.2 | 5.3 |
| 1100 | 228 | 1.8 | 4.9 |
| 1105 | 298 | 2.8 | 6.1 |
| 1110 | 336 | 1.6 | 4.8 |
| 1115 | 1 | 1.6 | 3.4 |
| 1120 | 309 | 1.6 | 6.7 |
| 1125 | 296 | 3.4 | 9.1 |
| 1130 | 263 | 4.4 | 6.7 |
| 1135 | 316 | 3.6 | 8.6 |
| 1140 | 297 | 2.6 | 6.3 |
| 1145 | 271 | 5.5 | 8.2 |
| 1150 | 219 | 3 | 7.2 |
| 1155 | 282 | 3.5 | 8.8 |

- NOTES -

- Date: 30 May 1997
- Wind speed measured 10 m above ground, vicinity of hangar
- Data represents 5-min averages, with max value within each 5-min window
- Wind direction is “from”, w/ respect to true North (14.8° west of magnetic North)
- Air pressure was fairly constant at 870.65 ± 0.15 Mb from 1000 hrs to 1200 hrs

# Wind Data (2 of 2)

| | | Speed (knots) | |
|---|---|---|---|
| Local Time | Direction | Avg | Max |
| 1200 | 226 | 3.9 | 8.4 |
| 1205 | 333 | 4.3 | 8.6 |
| 1210 | 2 | 4 | 8.4 |
| 1215 | 337 | 6.2 | 11 |
| 1220 | 8 | 2.2 | 12.2 |
| 1225 | 264 | 2.1 | 6.7 |
| 1230 | 269 | 2.9 | 8.2 |
| 1235 | 36 | 1.1 | 5.1 |
| 1240 | 69 | 2.7 | 5.9 |
| 1245 | 146 | 1.8 | 5.1 |
| 1250 | 259 | 5.9 | 9.3 |
| 1255 | 280 | 5.3 | 8.2 |
| 1300 | 287 | 2.4 | 5.3 |
| 1305 | 72 | 1.5 | 5.9 |
| 1310 | 116 | 0.8 | 5.9 |
| 1315 | 243 | 6.1 | 10.8 |
| 1320 | 256 | 3.9 | 7.8 |
| 1325 | 331 | 3.7 | 6.3 |
| 1330 | 345 | 2.2 | 5.1 |
| 1335 | 338 | 4.6 | 10.5 |
| 1340 | 26 | 6.3 | 9.9 |
| 1345 | 32 | 7.8 | 12 |
| 1350 | 360 | 3.4 | 6.1 |
| 1355 | 354 | 3.9 | 7.2 |
| 1400 | 28 | 2.9 | 8.8 |

- NOTES -

- Date: 30 May 1997
- Wind speed measured 10 m above ground
- Data represents 5-min averages, with max value within each 5-min window
- Wind direction is “from”, w/ respect to true North (14.8° west of magnetic North)
- Air pressure decreased linearly from 870.4 to 869.3 Mb between 1200 and 1400 hrs

# Vertical Temperature Profile Data (inside hangar)

| | Degrees C at height above floor | | | |
|---|---|---|---|---|
| Local Time | 2 m | 4 m | 6 m | 8 m |
| 1000 | 24.31 | 24.37 | 24.38 | 25.65 |
| 1010 | 24.58 | 24.68 | 24.69 | 25.95 |
| 1020 | 24.81 | 24.91 | 24.93 | 26.19 |
| 1030 | 25.08 | 25.19 | 25.22 | 26.49 |
| 1040 | 25.24 | 25.42 | 25.54 | 26.87 |
| 1050 | 25.4 | 25.72 | 25.95 | 27.34 |
| 1100 | 25.61 | 25.97 | 26.32 | 27.66 |
| 1110 | 25.83 | 26.2 | 26.65 | 28.05 |
| 1120 | 26.08 | 26.46 | 26.92 | 28.32 |
| 1130 | 26.28 | 26.67 | 27.15 | 28.62 |
| 1140 | 26.41 | 26.87 | 27.44 | 28.88 |
| 1150 | 26.64 | 27.08 | 27.63 | 29.12 |
| 1200 | 26.83 | 27.25 | 27.86 | 29.32 |
| 1210 | 27.01 | 27.42 | 28.04 | 29.59 |
| 1220 | 27.25 | 27.68 | 28.28 | 29.78 |
| 1230 | 27.47 | 27.83 | 28.54 | 30.07 |
| 1240 | 27.58 | 28.02 | 28.77 | 30.34 |
| 1250 | 27.75 | 28.19 | 28.99 | 30.63 |
| 1300 | 27.94 | 28.37 | 29.25 | 30.87 |
| 1310 | 28.1 | 28.5 | 29.47 | 31.14 |
| 1320 | 28.29 | 28.79 | 29.68 | 31.32 |
| 1330 | 28.41 | 28.94 | 29.78 | 31.37 |
| 1340 | 28.55 | 29.13 | 29.86 | 31.48 |
| 1350 | 28.61 | 29.22 | 30.05 | 31.64 |
| 1400 | 28.28 | 29.05 | 30.16 | 31.74 |

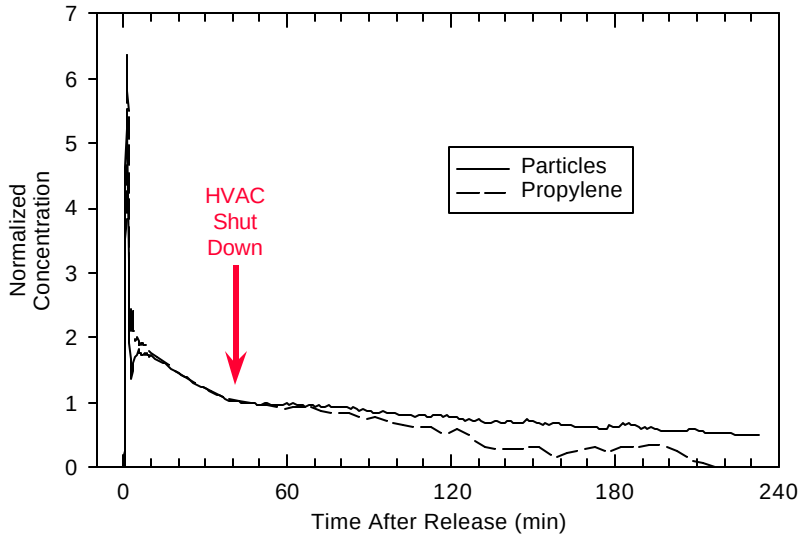
- NOTES -

- Date: 30 May 1997
- Sensor location (see sketch map):

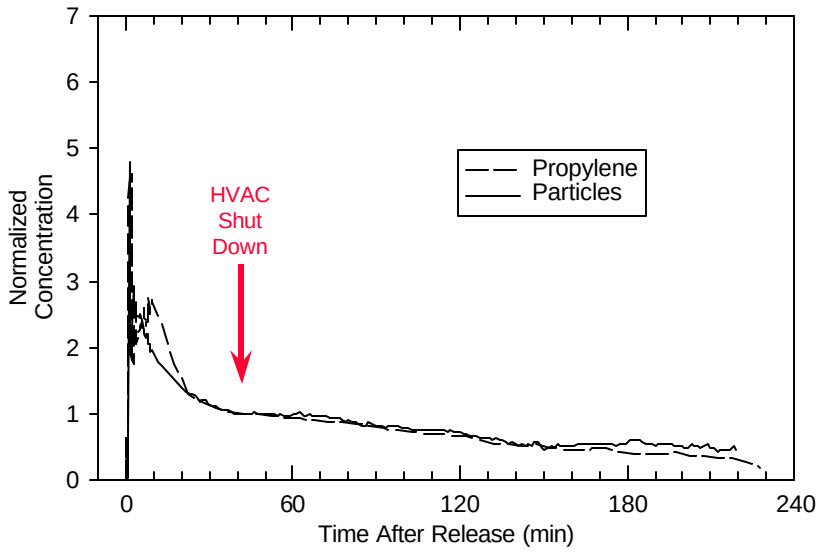
x = 12.20 y = -1.20 z = 2,4,6, and 8

- HVAC system turned off at 1040 hrs
- Only the 8 m sensor is above the level of the HVAC exhaust outlets.

# Propylene vs. Aerosol (Posn 4)



## Propylene vs. Aerosol (Posn 11)



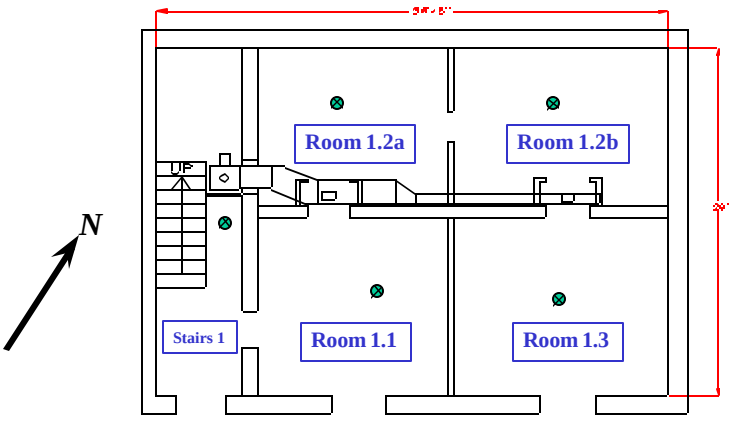

## Scenario 2

- **Simulated clandestine lab with accidental release in apartment/townhouse complex**
- **Dugway's German Village used to represent building**
- **Installed air handling system, simulated lab equipment**
- **Instrumentation suite installed**
  - Meteorology
  - Tracer gas detectors (in every room)
- **Measured building leakage rates**

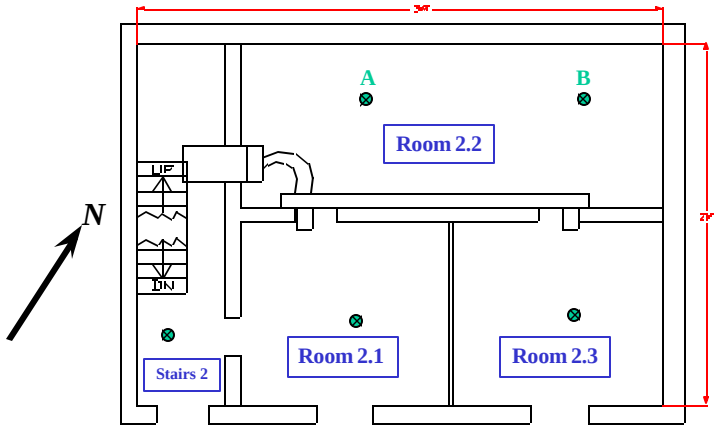
## Terrorist Hideout/Laboratory at “German Village"


Note: View is looking North.

## GV First Floor Schematic

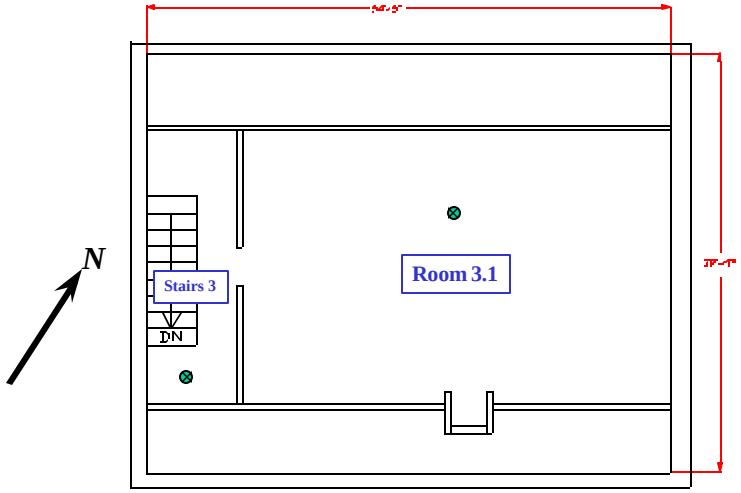


# GV Second Floor Schematic




Sensor locations

# GV Third Floor Schematic




Sensor locations

# German Village Room Volumes

| Room | Volume ($m^3$) |
|---|---|
| Stair 1 | 45.60 |
| 1.1 | 47.57 |
| 1.2 (includes 1.2a and b) | 90.17 |
| 1.3 | 47.91 |
| Stair 2 | 45.60 |
| 2.1 | 47.86 |
| 2.2 | 96.01 |
| 2.3 | 47.20 |
| Stair 3 | 23.92 |
| 3.1 | 188.15 |
| Total Ductwork | 1.91 |
| **TOTAL** | **681.90** |

# German Village Leakage Rates

Leakage characterized by the equation: $Q = C_i \ \Delta P^{-0.61}$

| Leakage Path | $C_i$ ($m^3$/hr) |
|---|---|
| Room 1.1 to Outside | 25 |
| Room 1.1 to Staircase | 74 |
| Room 1.1 to Room 1.2 | 202 |
| Door Room 1.1 to Room 1.2 | 43 |
| Room 1.1 to Room 1.3 | 0 |
| Room 1.1 to Room 2.1 | 3 |
| Door Room 1.1 to Staircase | 25 |
| Room 1.2 to Outside | 4 |
| Room 1.2 to Staircase | 28 |
| Room 1.2 to Room 1.3 | 202 |
| Room 1.2 to Room 2.2 | 14 |
| Door Room 1.2 to Room 1.3 | 43 |
| Room 1.3 to Outside | 58 |
| Room 1.3 to Room 2.3 | 8 |
| Room 2.1 to Outside | 41 |
| Room 2.1 to Staircase | 71 |
| Door Room 2.1 to Staircase | 102 |
| Room 2.1 to Room 2.2 | 122 |

| Leakage Path | $C_i$ ($m^3$/hr) |
|---|---|
| Door Room 2.1 to Room 2.2 | 16 |
| Room 2.1 to Room 2.3 | 65 |
| Room 2.1 to Room 3.1 | 14 |
| Room 2.2 to Outside | 8 |
| Room 2.2 to Staircase | 5 |
| Room 2.2 to Room 2.3 | 136 |
| Door Room 2.2 to Room 2.3 | 117 |
| Room 2.2 to Room 3.1 | 145 |
| Room 2.3 to Outside | 25 |
| Room 2.3 to Room 3.1 | 8 |
| Room 3.1 to Outside | 921 |
| Room 3.1 to Staircase | 197 |
| Door Room 3.1 to Staircase | 30 |
| Staircase to Outside | 105 |
| Door Staircase to Outside | 10 |
| Duct System to Staircase | 10 |
| Duct System to Room 1.2 | 30 |
| Duct System to Room 2.2 | 12 |

# Measured HVAC Flow Rates

| HVAC Register ID | Register Flow Rate ($m^3$/hr) |
|---|---|
| Supply to Room 1.1 | 126.8 |
| Supply to Room 1.2a | 170.8 |
| Supply to Room 1.2b | 175.9 |
| Supply to Room 1.3 | 217.8 |
| Supply to Room 2.1 | 244.2 |
| Supply to Room 2.2a | 161.0 |
| Supply to Room 2.2b | 199.4 |
| Supply to Room 2.3 | 234.4 |
| Total Supply | 1530.3 |
| Return | 1846.1 |
| Total Duct Leakage* | 315.8 |

* Discrepancy between supply and return flows for the HVAC system is due to leakage from the ducts.

# Propylene Trials - Summary

| Trial Number | Date | Start Time | End Time | Propylene Release Location | Doors | HVAC System |
|---|---|---|---|---|---|---|
| GV1 | 21-Oct-97 | 8:50 | 12:00 | HVAC RETURN | ALL OPEN | ON |
| GV2 | 21-Oct-97 | 13:30 | 15:30 | HVAC RETURN | STAIRWELL CLOSED | ON |
| GV3 | 21-Oct-97 | 16:50 | 19:15 | HVAC RETURN | ALL CLOSED | ON |
| GV4 | 22-Oct-97 | 8:45 | 11:00 | ROOM 1.3 | STAIRWELL CLOSED | ON |
| GV5 | 22-Oct-97 | 12:05 | 15:20 | HVAC RETURN | ALL OPEN | ON |
| GV6 | 23-Oct-97 | 9:00 | 11:20 | HVAC RETURN | STAIRWELL CLOSED | ON |
| GV7 | 23-Oct-97 | | | No Data | | |
| GV8 | 24-Oct-97 | 9:35 | 11:45 | HVAC RETURN | ALL CLOSED | ON |
| GV9 | 24-Oct-97 | 12:35 | 14:15 | ROOM 1.3 | STAIRWELL CLOSED | ON |
| GV10 | 24-Oct-97 | 15:10 | 17:10 | HVAC RETURN | ALL OPEN | ON |
| GV11 | 25-Oct-97 | 9:05 | 11:05 | HVAC RETURN | STAIRWELL CLOSED | ON |
| GV12 | 25-Oct-97 | 12:30 | 2:35 | HVAC RETURN | ALL CLOSED | ON |
| GV13 | 25-Oct-97 | 15:56 | 20:15 | ROOM 1.3 | STAIRWELL CLOSED | OFF |

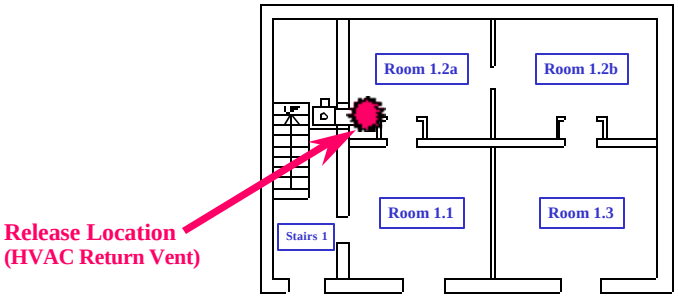
**Notes:**

1. All times are local (Mountain Daylight).
2. Each release comprised 24 to 28 grams of propylene (varied by trial), released from balloons popped at the listed start times.
3. The door between rooms 1.2a and 1.2b was open for all trials.

# Propylene Trial GV01

**Conditions of Release:**

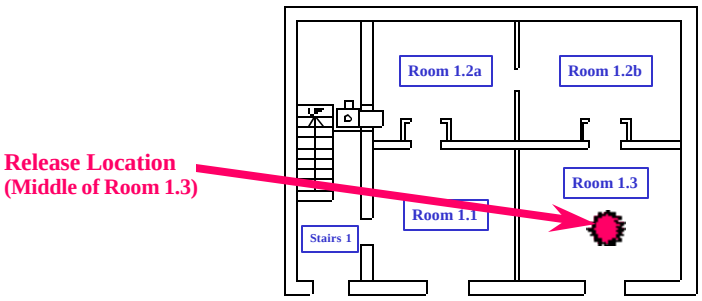
- 24 grams of propylene in balloons
- Balloons popped at 0850 hrs, Mountain Daylight Time, 21 Oct 97
- HVAC system was running the whole time
- All doors in the building were open (except the 1st floor door to the outside)
- Ambient: Light and variable winds (<0.7 m/sec), ~10°C, 874 mb pressure.



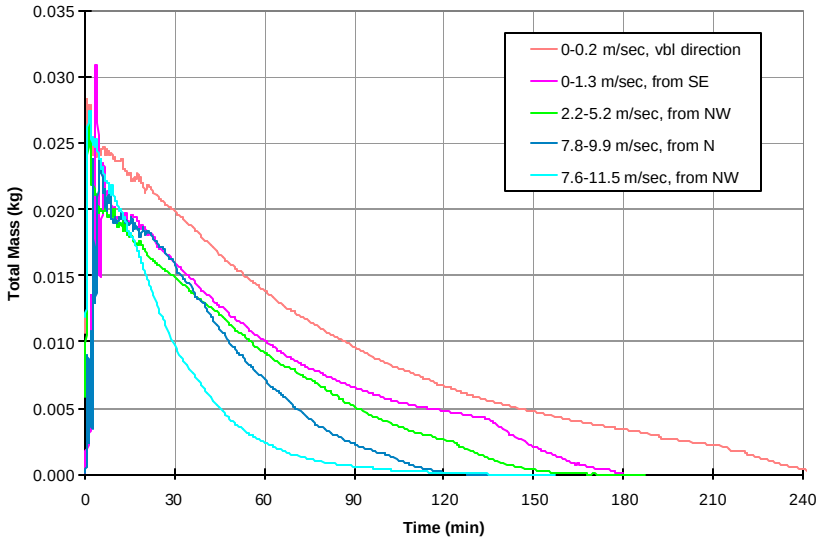

# Propylene Trial GV04

**Conditions of Release:**

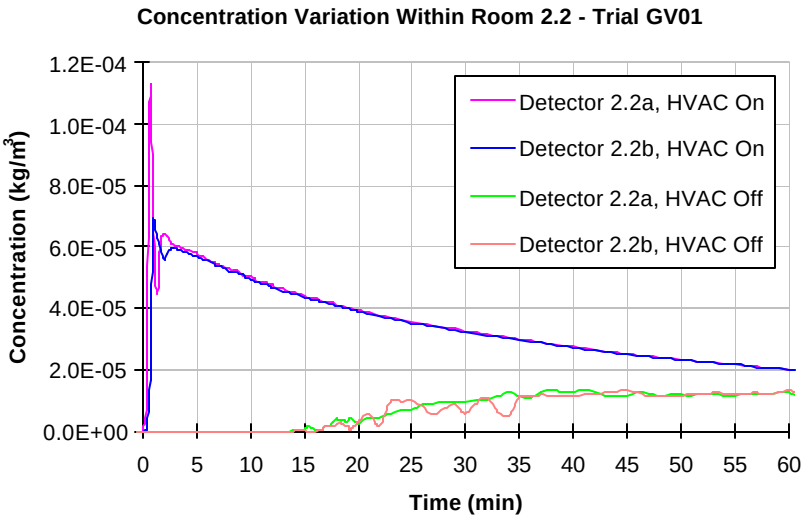
- 25 grams of propylene in balloons
- Balloons popped at 0845 hrs, Mountain Daylight Time, 22 Oct 97
- HVAC system was running the whole time
- Doors to the stairwell on each floor were closed, all others open
- Ambient: Light winds (<1.3 m/sec) from SE, 870 mb pressure, temp increasing from 1.7° to 15°C



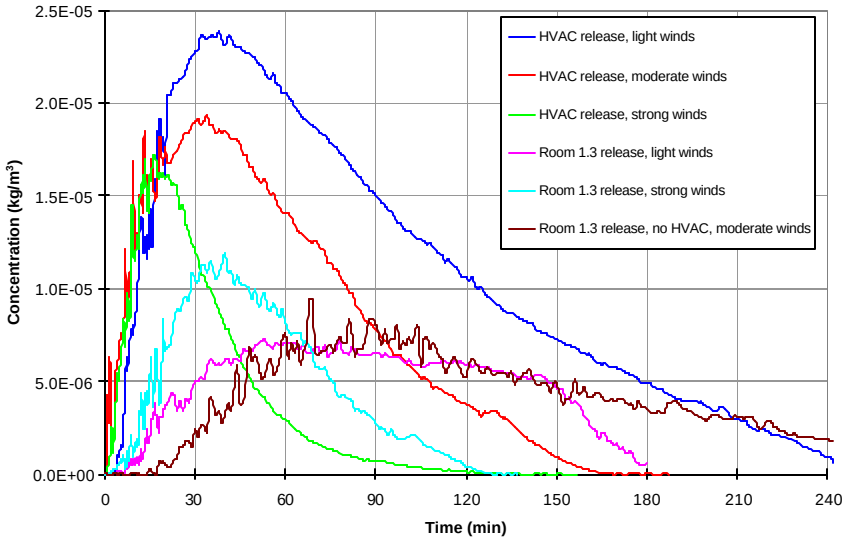
# Leakage vs. Wind Conditions



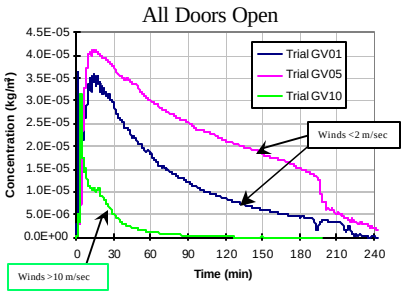

# Concentration Variability w/in a Room

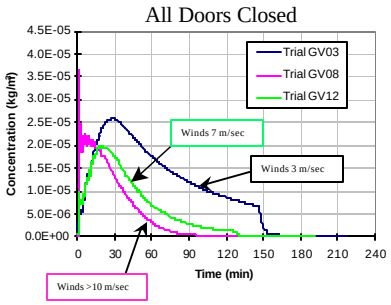


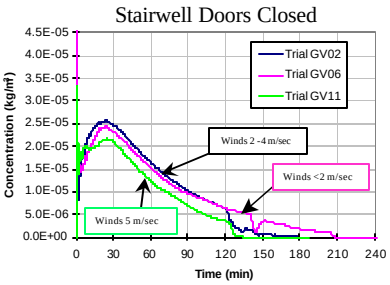
# Attic (Room 3.1) Concentration




# Data Reproducability

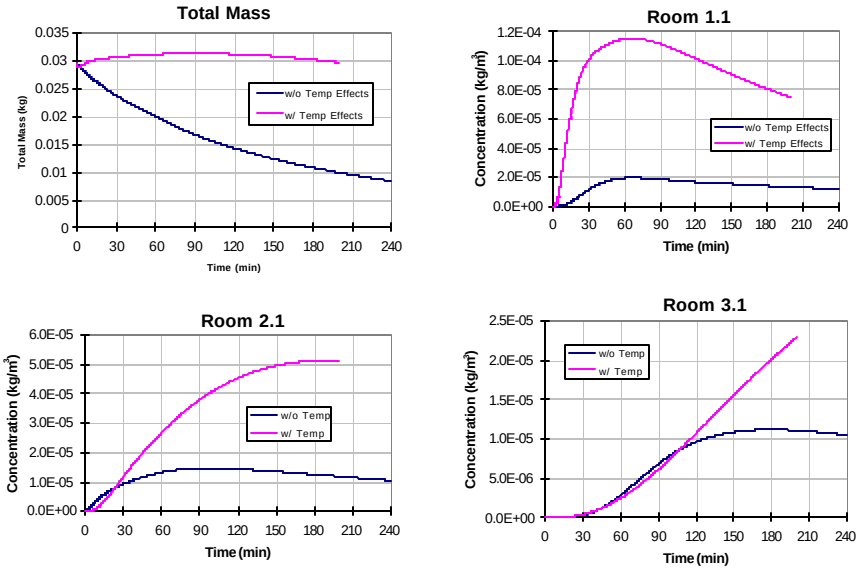



- All data for Room 1.1
- Propylene released into HVAC return vent
- Wind conditions as labeled

# Temperature Effects




# Access to the Data

- **911-Bio ACTD Final Report distributed through Defense Threat Reduction Agency, Chemical Biological Defense Directorate**
  - FOUO
  - Contains M&S data plus hardware and CONOPS assessments
- **Interior Building Ground Truth data being prepared as a separate package (independently releasable)**
  - Requests should be directed to DTRA/CB
- **M&S data archive maintained by DGI**
  - Facility data in Word tables and PDF files
  - Concentration data in Excel spreadsheet format
  - Meteorological data in Word tables and Excel